SHANGHAI SYNCHROTRON RADIATION FACILITY

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Abstract

The Shanghai Synchrotron Radiation Facility (SSRF) was proposed by the Chinese Academy of Sciences and the Shanghai Municipal Government in 1995. The estimated total budget is around 120M USD, and the operation is scheduled to begin by the end of 2004. Although the whole SSRF project is still awaiting final approval, its R&D has been approved already. The SSRF is a third generation light source designed to produce high brightness and flux soft X-ray and hard X-ray in the energy region of 0.1~40keV. It consists of a 300MeV linac, a 3.5GeV booster, a 3.5GeV storage ring and dozens of beam lines and experimental stations. In this paper, the main parameters and features of the SSRF are presented.

1 INTRODUCTION

In order to meet the growing demand for synchrotron radiation application in China, the Chinese Academy of Sciences (CAS) and the Shanghai Municipal Government (SMG) made a joint proposal for constructing an advanced third generation light source, namely, the Shanghai Synchrotron Radiation Facility (SSRF), in 1995. The SMG promised to contribute one third of the total project budget, and the CAS took the scientific and technical guarantee for the project. One year later the draft of the SSRF conceptual design was completed and positively reviewed by an international review committee in September of 1996. Then the R&D of the SSRF project was approved by the state in 1997, and the 80M Chinese Yuan budget for this R&D was allocated in 1998. For assuring the success of the project construction, the leading group of the SSRF was set up by the CAS and the SMG with the president of the CAS as its head and the executive deputy mayor of the SMG and a vice minister of the Ministry of Science and Technology of China as its deputy heads in September of 1998. Since then the R&D of the SSRF has been undertaken.

2 DESIGN OVERVIEW

2.1 Design Goal

The purpose to construct the SSRF is to establish a multidiscipline frontier research center and a high-tech R&D base in order to offer attractive research opportunities for a wide variety of fields in China.

The requirements of the CAS and the SMG on the construction of the SSRF are as follows. (1) The performance of the SSRF should be better than that of the present existing third generation light sources at the same energy region, and be at the forefront of its kind when it is completed at the beginning of the 21st century. (2) The research lifetime must be longer than 20~30 years after its establishment. (3) And its budget should be around 120M USD. They are quite ambitious.

Since the largest part of user community in China works in the X-ray region of spectrum 4-40keV and the second largest in the soft X-ray region of 0.1~4keV, the SSRF is designed to produce high brightness and flux X-ray in the energy region of 0.1~40keV.

2.2 Design Modification

In the initial design [1] of the SSRF, the nominal energy of the SSRF storage ring is 2.2GeV, so actually the SSRF would be a VUV and soft X-ray light source even its energy can be upgraded to 2.5GeV, it cannot fully meet the user demands. This is mainly due to the budget limitation. The emphasis of the former design is laid on reaching low emittance, therefore the brightness of the SSRF would be higher than that of currently operating VUV and soft X-ray third generation light sources. After examining other alternatives, the modified TBA lattice structure with the emittance of 3~4nm-rad and the circumference of 345m is chosen for the SSRF storage ring. In order to provide the capability of the hard X-ray with the energy extending to 60keV, several normal bending magnets can be replaced by superconducting dipoles. Furthermore two super long straight sections of 18m are preserved for the potential use in the future.

Considering seriously the suggestions [2] of the experts attending the 96' International Review Meeting on the Concept Design Report of the SSRF, and the sharp increase of the user demand for X-ray and hard X-ray, we have modified the SSRF design goal to greatly increase the brightness of the energy spectrum in hard X-ray region and make the SSRF cover much wider spectrum by increasing the design energy to 3.5GeV with adding a little investment, so that the SSRF has a better cost-effectiveness. In the new design, we sacrifice the performance of the SSRF in VUV and soft X-ray region and give up the original goal of providing the brightest beam in the photon energies below 3keV. To meet the design goal, several possible lattice structures including DBA [3] and modified TBA[4] types have been studied, and are available for the SSRF. For simplicity we adopted the DBA lattice structure.

3 MACHINE FEATURES

The SSRF complex sketched in Fig.1 consists of three major parts, a full energy injector including a 300MeV linac and a 3.5GeV booster as well as the corresponding beam transport lines, a 3.5GeV storage ring and the synchrotron radiation experimental facilities.

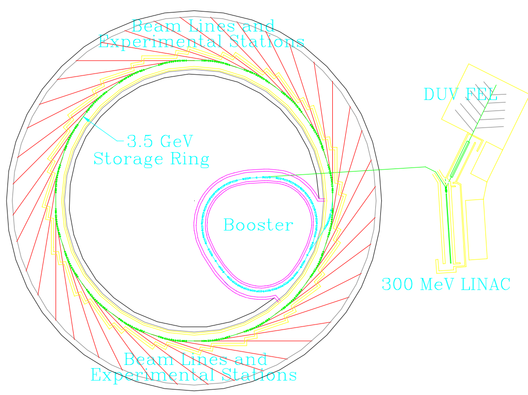

Fig.1 Layout of the SSRF

3.1 Lattice

The new lattice of the SSRF storage ring is a double-bend achromat structure. It is composed of 20 cells with 10 of 6.6 m and 10 of 4.6m long dispersion-free straight sections. The circumference of the storage ring is 384m. Each asymmetrical DBA cell contains 2 bending magnets, 10 focusing quadrupoles and 7 sextupoles. Its linear lattice functions are shown in Fig.2.

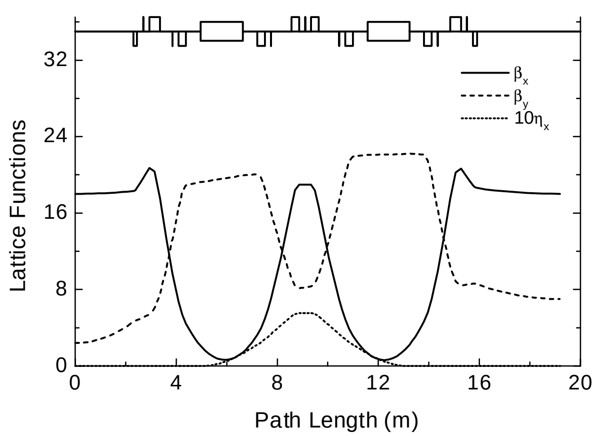

Fig.2 Lattice functions for one cell

There are altogether 4 families of sextupole, in which two of them located at the achromatic arc are used to correct chromaticities, and the other two families distributed in the non-dispersive region are used for harmonic correction to improve the dynamic aperture as well as the energy acceptance. After tentative optimisation, the horizontal and vertical dynamic apertures off momentum (±3%) with multipole field errors at the injection point reach ±20 mm and ±18mm respectively, as shown in Fig.3. And the energy acceptance of the ring is larger than 3%.

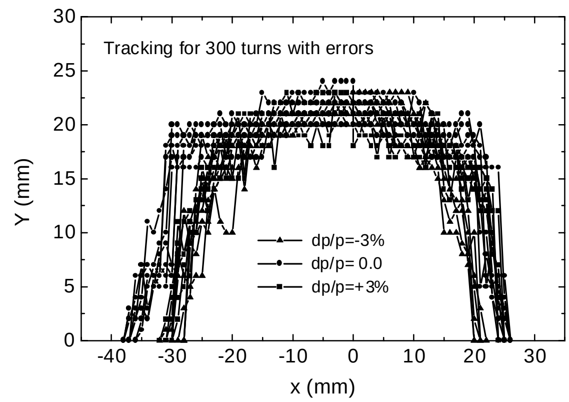

Fig. 3 Dynamic aperture at the injection point

Besides, the effects of magnetic imperfect, the closed orbit distortion and correction, the effects of insertion devices, the beam instabilities and the beam lifetime, the injection and etc. have been preliminarily studied, they also meet the design requirement. The storage ring optics with non-zero dispersion in the straight sections has been examined, giving a reduction factor of about 2 in the beam emittance. Now the lattice optimisation of the storage ring is still underway.

3.2 Main Parameters of the Storage Ring

Energy	3.5 GeV
Circumference	384 m
Natural Horizontal Emittance (rms)	12.1 nm·rad
Beam Current (multi-bunch)	200-300 mA
(single bunch)	>5 mA
Number of cells	20
Insertion Straight Sections	6.6m10,4.6m 1 0
Magnetic filed , normal dipole	1.104 T
Number of quadrupoles	200
Max. gradient for quads	18.5 T/m
Number of Sextupoles	140
Max. sextupole strength	450 T/m^2
Betatron tunes, Q_x/Q_y	18.22/7.18
Natural Chromaticities ξ_x/ξ_y	-45.1/-20.8
Momentum compaction	7.1×10^{-4}
Harmonic number	640
Radio Frequency	499.65 MHz
RF Voltage	4.0 MV
Energy Loss per Turn	1.256 MeV
Bunch Length (rms) σ_s	4.87 mm
Beam Lifetime	>20 hrs

3.3 Photon Brightness and Flux

Fig.4 and Fig.5 show the brightness and flux of the SSRF under the current existing insertion devices. Comparing with the original design, after the modification, the high harmonics from undulators could provide X-ray beams of 7~20keV with a brightness of about 10^{17} or higher, 3 or more orders of magnitude higher than that from the super -conducing bending magnet in the original SSRF design. This significant increase in hard X-ray brightness is the most important feature of the SSRF. In addition, the larger emittance and the higher electron energy will greatly increase the beam lifetime and also the dynamic aperture of the storage ring. Another advantage of this design is that the 300MeV SSRF linac could be used meanwhile for the application research of the DUV FEL (Deep Ultra Violet Free Electron Laser).

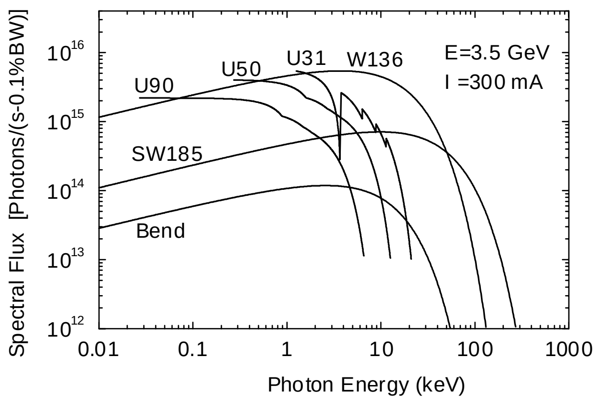

Fig. 4 Spectral Flux of SSRF

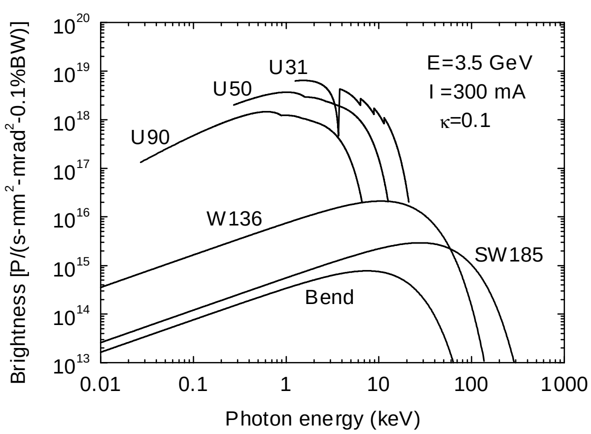

Fig. 5 Spectral Brightness of SSRF

In short, the new design might be considered the best in cost-effectiveness over a broad spectral range and the SSRF will be close to the best in the world over a spectral range extending from the VUV to the hard X-ray with a little more cost.

Moreover, 7 beam lines and experimental stations for the first phase construction were selected by the first SSRF Users' Meeting last December, they are for macromolecular crystallography, X-ray absorption fine structure spectroscopy, high resolution diffraction and scattering, microfocusing, medical application, soft X-ray coherent microscopy and LIGA.

4 COST ESTIMATE AND SCHEDULE

On the basis of the information acquired from domestic and foreign industries as well as some light source laboratories in the world, the preliminarily estimated cost of the SSRF is around 1 Billion Chinese Yuan (in the FY of 1998, excluding management cost and staff wages). Of course, the final estimated cost will be achieved when we complete the detailed design and the R&D of the SSRF.

To catch up with the development of synchrotron radiation application in the world, we shall strive to make the SSRF one of the advanced third generation synchrotron radiation facilities that will be operated at the beginning of the 21st century. The tentative project schedule has been proposed under the important prerequisite that the whole SSRF project should be approved before the middle of 2000 by the Chinese government. The proposed overall schedule of the SSRF project is to start the light source commissioning in April of 2004 and to run it for the users from the following October.

5 ACKNOWLEDGMENT

This work was supported by the Chinese Academy of Sciences and the Shanghai Municipal Government and performed by the SSRF project team. Particularly, our colleagues, Z. M. Dai, G. M. Liu and L. M. Chen, have played an important role in the design of the storage ring lattice. We are also thankful to Dr. H. Winick, M. Ando, A. Chao, C. T. Chen, J. Galayda, H. Hsieh, H. Kamitsubo, S. Krinsky, F. Schlachter, R. Schlueter, L. Teng, E. Weihreter, W. T. Weng and A. Wrulich, etc. for their important consultation, useful comments, helpful suggestions and discussions on the review of the CDR of the SSRF.

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